as that of "brittle" zinc, and the lines of fracture ran across the crystals revealed on the changed surface in such a way as to show that these crystals seen on the surface are not a thin superficial layer, but genuinely represent the entire structure of the metal.

I am therefore led to the conclusion that the action is simply one of recrystallisation. The metal in the state in which it reaches us in foil or crucibles, &c., is in a condition of severe strain, having been bent, drawn, rolled, &c., either in the cold or at temperatures far below its "annealing" temperature. This is supported by the fact that the platinum in its "unchanged" state shows a very minute structure characteristic of severely strained metals. The natural effect of exposure to a high temperature of metal in such a condition is to allow it to recrystallise, and this I conceive to be what occurs in the case of platinum. The brittleness of the "annealed" metal is not at all surprising, as the same phenomenon occurs with zinc and cadmium (see paper cited above). In the case of platinum "annealed" in a gas flame there is, however, a further action; simple annealing or recrystallisation, although it will completely alter the interior structure of a piece of metal, will not of itself alter the appearance of the surface even in microscopic detail. To develop a surface pattern corresponding to the changed internal structure the surface must be *etched after* the recrystallisation has taken place. The etching action is in this case undoubtedly due to the gases of the flame, and the temporary formation of a carbide may play a part in this process.

"On some Phenomena affecting the Transmission of Electric Waves over the Surface of the Sea and Earth." By Captain H. B. Jackson, R.N., F.R.S.

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In 1895, systematic experiments were commenced by me with a view of utilising the effect of Hertzian waves on imperfect electrical contacts, for naval signalling purposes.

I soon observed that some unexpected phenomena were deterrent factors in obtaining the necessary accuracy at all times, and with the most modern and improved instruments that we now possess, this is equally noticeable.

The results of some of the phenomena are described in this paper, with the conclusions that I have drawn as to their cause.

Some of the experiments described were specially conducted with the object of elucidating definite results on the subject. Other experiments carried out with a different object, and also ordinary practical signalling at various times, also gave the results described, without in any way detracting from their value on account of the main object in view being at the time of a different nature.

One of the great difficulties in accurately comparing results, separated by even the shortest intervals of time in wireless telegraphy, is, undoubtedly, in having to depend on an imperfect electrical contact for the comparison, as even the best coherers, as they are now generally termed, cannot be depended upon to give absolutely similar consecutive indications, under similar conditions of excitation; and in the filings coherer, for instance, which I have chiefly used, the probability is infinitesimally small that the filings will rearrange themselves identically, in any two successive signals, taking into account the shaking to which they are subjected immediately following the reception of an excitation; though the practical results obtained with those of good manufacture might almost lead one to an opposite opinion, owing to the accuracy with which signals are generally recorded. Careful observation over an extended period has led me to the conclusion that the error arising from this cause in the experiments described does not exceed 5 per cent., *i.e.*, in any one hundred consecutive signs in a series of signals, ninety-five of them will be accurately recorded at the distance where the excitation is nearing the limits at which it will affect the coherer. At shorter distances, with moderately strong excitations, the error is much less, probably less than 1 per cent. Experiments conducted under favourable circumstances, with the object of obtaining the percentage of accuracy, have frequently confirmed this. The method used to carry this out was to select a long signal whose details were known, and count the errors in the number of signs composing the signal.

Though a possible error of 5 per cent. in any experiment may, in systematic comparative trials, or quantitative analysis, appear large, this error may be considered to be eliminated when the mean of a considerable number of excitations is taken, and the results judged by the general effect, which was whether or no excitations were received at a given distance for a considerable period of time. For instance: the experiments, as a rule, consisted in one station sending signals consecutively for (say) 2 minutes, at the rate of 100 signs a minute. If these signals were received correctly, or nearly so, the receiving station was considered to be within the limits at which signals could be received under those circumstances; if only 50 to 90 per cent. of the signs were received, it was considered at the extreme limit of signalling distance; if 20 to 50 per cent. were received, it was considered to be just outside the limits; if less than 20 per cent., or, as frequently occurred, no signs were received, it was considered to be beyond the limits of signalling. In the two latter cases, careful inquiry and examination of the records of the transmitting station were always made to prove that the signals had actually been sent at that time. At the conclusion of the 2 minutes, the receiving ship, by means of a short prearranged signal, acknowledged the signals, if received, and stated whether they were clear or broken, or if none had been received. To still further reduce any chance of error, two coherers, or, rather, two complete receivers, were generally used; they were adjusted to be of equal sensitiveness, or nearly so, and they were used alternately, for about 15 seconds each, or else together, *i.e.*, in parallel. Local excitation of these coherers was also frequently resorted to, as by this means, if the filings have by chance rested in an insensitive position, their excitation and shaking gives the possibility that they may rearrange themselves more sensitively.

The experiments recorded have, with few exceptions, been carried out under my own personal supervision at one of the stations, and the recording tapes of the receivers were invariably compared with the written notes and log of the transmitting stations, at the earliest opportunity afterwards.

The distances up to which I have carried out experiments, reach 140 nautical miles. In my early experiments, before wireless telegraphy had developed into its present stage, the distances were comparatively short, though the results were equally instructive. In the tables of records, in addition to stating the actual distances, the results are compared to a maximum distance of 100, which represents that obtained at sea under the same circumstances, but without the disturbing causes whose effects were under consideration at the time; so the percentage of loss of distance, under varying circumstances, may be easily compared.

The trials were all carried out under practical sea-going conditions, and though these may militate against the absolute accuracy obtainable in laboratory experiments, they may eliminate some errors which may affect the observations of Hertzian waves in a closed building, such as the reflection of the waves from the surrounding walls.

The instruments used were those constructed on what is generally known as the Marconi System, and were either supplied by his company or made to my design for the Admiralty; these types only differ in details.

As a rule, for transmitting signals, an aerial wire or wires were attached to one of two spark balls fitted to an induction coil, the other ball being earthed; when, however, my system of syntonic transmission was used, the connection of the aerial was not as above; this system is indicated by inserting (T) against the results. The induction coils employed have been those capable of giving a 10-inch spark between points in dry air. In all the experiments herein detailed, a jigger, *i.e.*, a small transformer, was used in the aerial wire of the receiving instruments. The aerial wires of all ships and stations were tuned as closely as possible to the same natural frequency of oscillation, and the jiggers were constructed to receive signals at the maximum distance corresponding to the power and frequency used at the transmitting station. The fundamental wave-length was that adopted in H.M.'s service, except when my syntonic system was used, in which case large variations in the wave-lengths were tried. Syntonic wireless telegraphy, however, is not considered in this paper.

The results, when tabulated, demonstrate the loss in distance that may be experienced when signalling by means of wireless telegraphy under varying conditions of the atmosphere, and the environment of the ship as regards land compared with the distance obtained under favourable conditions in the open sea. In fact, they show some of the causes which may affect the transmission of waves of electrical induction from an aerial wire over the surface of the globe. The causes are treated in the same order as I observed them in the practical work of wireless telegraphy, and the first case that I consider is the effect of intervening land on the distance at which signals can be recorded.

This effect, without any recorded exception, is to reduce the maximum distance of signalling from that recorded in the open sea by an amount depending upon the thickness, contour, height, and nature of the land. The curvature of the Earth and its effect on the waves is not taken into account, as at the distances covered in these experiments no effect has been noticed, though carefully watched for when signalling with stations high above the sea-level.

The effects of intervening land are shown for a few typical and well-authenticated cases, and where no other cause or known source of error existed, in the form of diagrams and tables. In the latter the heights of the mastheads or aerial wires are indicated, also the distance of the intervening land from the ship nearest to it, &c. The particulars of the land, the distances at which signals could just be clearly received, and the ratio of the distances at which signals were obtained over water under identical circumstances, and generally on the same day, are also inserted. The diagrams illustrate these details graphically, and show the general contour of the land and its strata. The vertical scale has been greatly exaggerated over the horizontal one, in order to present these data more clearly, and the ratio of the vertical to the horizontal scale is either 25 or $12\frac{1}{2}$, except in Nos. 4 and 5, where it is 32.

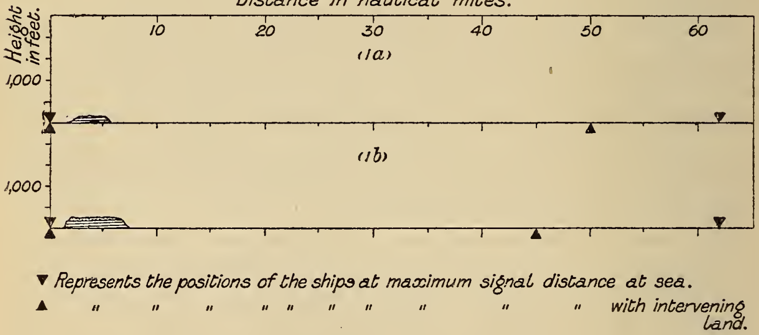
An examination of these results shows the marked difference between the effects due to the various natures of the intervening land.

Summarising them for soft rocks, hard limestone, and limestone containing a large proportion of iron ores respectively, the percentage of maximum signalling distance through them compared to the open-sea distance is as follows :—

	Soft sandstone, shale, &c.	Hard limestone.	Iron ores.
Max. distance	81	68	Less than 40
Min. "	56	25	" 23
Mean "	72	58	" 32

Consider, firstly, the soft rocks :—The two maxima percentages of distance (81 and 80) are over rather low land of no great thickness; the minimum, 56 per cent., is over high land, half as thick again as in these cases.

Fig. 1.



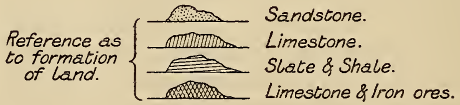
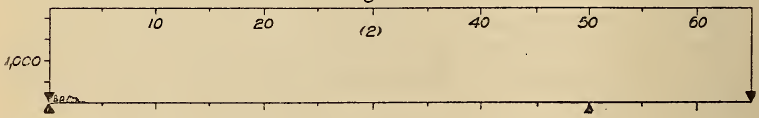


Fig. 2.

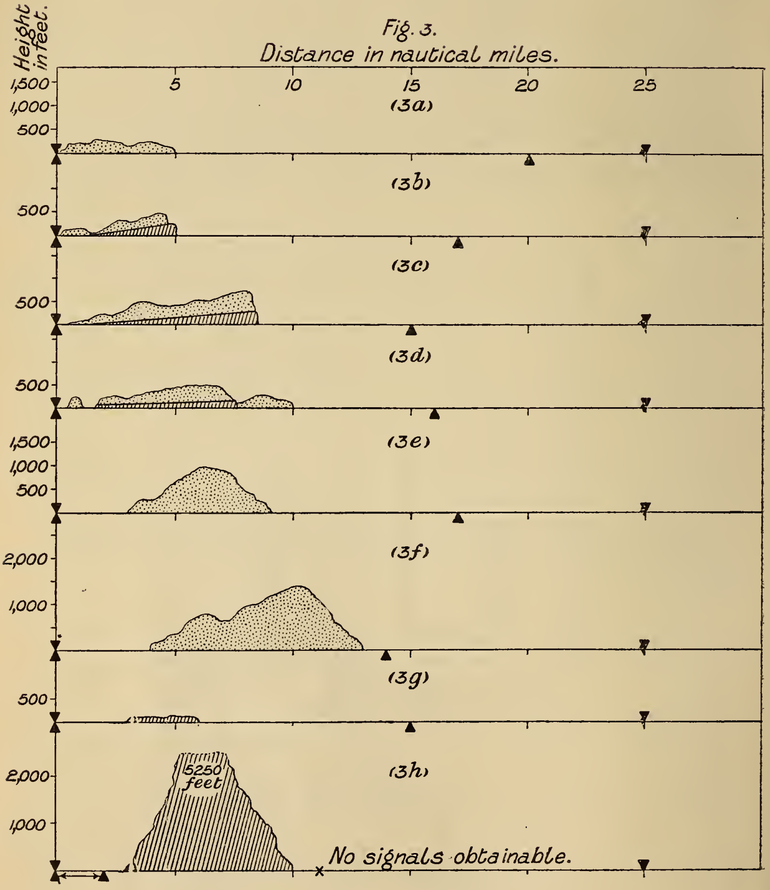


Secondly, the limestone :—The maximum percentage (68) is over the thinnest layer recorded of limestone (3 *b*), the minimum (less than 25) is over a precipitous high mountain through which no signals could be passed at any distance, though they were obtained without difficulty over a low promontory of the same island and of the same formation, when both ships had moved to such positions as to bring the low instead of the high land between them (figs. 3*h* and 3*g*).

Reference Table for the above Figures.

Reference number.	Height of aerial wire above sea.	Distance from the land.	Particulars of the land.				Height of aerial wire above sea.	Maximum signal distance.		Percentage of maximum distance over land to over sea.
			Maximum height.	Total thickness.	Formation, strata, &c.	Surface.		At sea.	Over the land.	
	feet.	miles.	feet.	miles.			feet.	miles.	miles.	
1*a*	158	2	150	4	Shale	Pasture, wet	178	62	50	81
1*b*	158	1¼	250	7	Sandstone and slate	do.	178	62	45	73
2	125	130 yards	200	2¼	Porous sandstone	Buildings, dry	160	65	50	77

Fig. 3.


Height in feet.
Distance in nautical miles.
5
10
15
20
25
1,500
1,000
500
(3a)
(3b)
500
(3c)
500
(3d)
500
(3e)
1,500
1,000
500
(3f)
2,000
1,000
(3g)
500
(3h)
2,000
1,000
5250 feet
No signals obtainable.

Reference number.	Height of aerial wire above sea.	Distance from the land.	Particulars of the land.				Height of aerial wire above sea.	Maximum signal distance.		Percentage of maximum distance over land to over sea.
			Maximum height.	Total thickness.	Formation, strata, &c.	Surface.		At sea.	Over the land.	
	feet.		feet.	miles.			feet.	miles.	miles.	
3*a*	125	250	250	6	Porous coral sandstone..	Cultivated, wet	160	25	20	80
3*b*	—	yds. 220	500	6	Do. over limestone	do.	—	—	17	68
3*c*	—	500	700	8	do.	do.	—	—	15	60
3*d*	—	1000	500	7	do.	do.	—	—	16	64
3*e*	160	3	1083	6	Gritstone and marl	Bare and dry, with scrub	125	—	17	68
3*f*	—	miles 4	1400	9	do.	do.	—	—	14	56
3*g*	—	3	120	3	Semi-crystalline limestone	do.	—	—	15	60
3*h*	—	1 to 2½	5250	7		do.	—	—	No signals.	Very small.

Thirdly, the rocks containing iron ores :—In all these cases a greater loss of proportional distance is recorded than in the others—and it was exceptional to receive any signals at all—and the best result recorded in several trials was but 39 per cent. of the open sea distance (fig. 5).

Fig 4.

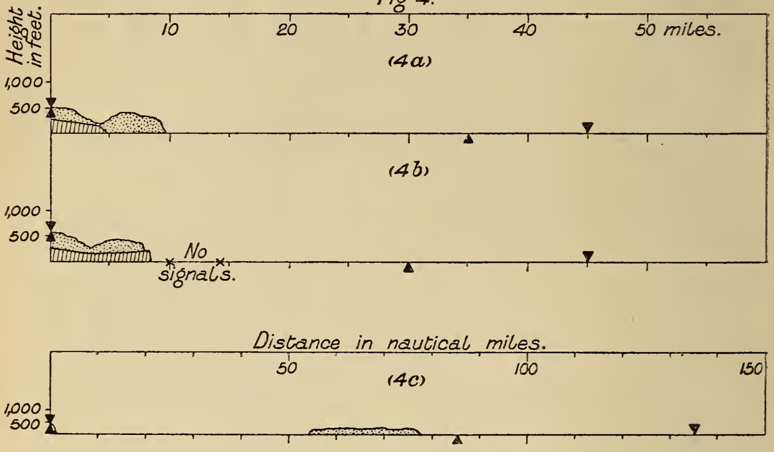


Fig. 5.

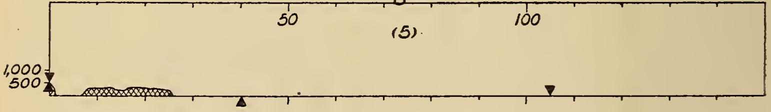
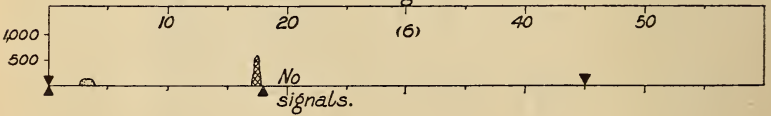


Fig. 6.



The results shown in fig. 6 are the most conclusive that I have obtained in proving the screening effect of hard rocks containing iron ores on the passage of electric waves through land. The pinnacle of rock shown therein represents an extremely precipitous, narrow, but high promontory jutting out from the mainland and rising abruptly out of the sea, to which it is *steep to*, so that the ship could pass close to it in perfect safety at a distance of about 100 yards.

To ascertain the effect of this wedge-like obstruction, the ship was steered close to the land, and her position was carefully noted when signals ceased or commenced. These signals were being sent continuously from another vessel (distant 18 miles) during the whole period of the trials, the letter F (– – —— –, in Morse Code) being

Reference number.	Height of aerial wire above sea.	Distance from the land.	Particulars of the land.				Height of aerial wire above sea.	Maximum signal distance.		Percentage of maximum distance over land to over sea.
			Maximum height.	Total thickness.	Formation, strata, &c.	Surface.		At sea.	Over the land.	
	feet.	miles.	feet.	miles.			feet.	miles.	miles.	
4*a*	160 + 500	On the land	500	9 over	Porous sandstone........	Cultivated, wet......	110	45	35	78 (T.)
4*b*	do.	—	600	8 over	Do., over limestone	do.	110	45	30, but none from 10 to 14	67 (T.)
4*c*	do.	—	400	22	Sandstone..............	do.	130	135	85 and over	Over 63
5	154 + 330	3	500	17	Limestone and iron ores..	do. wet and dry	125	105	40	39
6	125	100 yards	800	$\frac{1}{4}$	,, ,,	do. wet......	110	45	None at 18	Less than 40 (T.)

made by her at the rate of twenty-five per minute by my syntonic transmitter.

The results showed that the signals ceased and commenced abruptly at the moment that the aerial wire passed the tangent from the transmitting ship to the edge of the cliff; the action was so abrupt, that, on one transit, the latter part of the long sign in the "F" was the first indication of signals that was received; and on another transit, in the opposite direction, the long of the "F" was the last sign received, the short being dropped; these were unusual results, as the signals generally die away gradually, the long signs breaking up, thus: (. . . . . .), and the shorts appearing as dots (.), before any signs are actually lost.

Another point that may now be considered, is the case shown in fig. 4*b*, when signals could not be exchanged when the ship was close under the land, but could be when clear of the land and in the same direction as before; the trial was repeated on several occasions for verification.

Possibly the case previously considered, fig. 6, is of the same class, as it is noteworthy, that when the ship was further off the promontory and also from the transmitting ship, though the two ships were still masked by high land of much greater thickness than before, a few stray signals were received occasionally, which evidently passed over, not round, and not through the land, as the ship was then in a land-locked bay.

Referring now to figs. 3*e* and 3*f*, where the intervening land was both higher and thicker, and yet did not stop signals at longer proportional distances, it may be concluded that the waves of electrical induction, which must pass from ship to ship in order to record signals, may in certain cases pass through the land. Fig. 2 is a good example of this: one of the ships was lying alongside a perpendicular cliff of considerable height, and yet only experienced a loss of distance of about 12 per cent.

Fig. 8*a* gives a typical case of waves passing through valleys, and the results were so marked and so frequently repeated with different ships and on separate occasions that eventually the track of a vessel, proceeding at a known speed, could be roughly estimated, though distant 25 miles, by noting the intervals between the times when signals were lost and when received, and comparing these intervals with the time taken by the ship to cover the distances between the valleys, which were well delineated on the chart, and through which the waves could evidently wind their way with less obstruction than by any other route.

We have thus obtained evidence that the waves of electric induction may pass (1) through land, (2) over land, (3) round land, but that a large proportion of their energy is lost in doing so. (4) That the screening effect of the land varies with its nature, and is greater for iron ores than for limestone alone, and that for this latter, it is greater than for soft rocks. No effects which could be attributed to interference of waves, due to reflection from a hilly background, have been recorded by me.

Fig. 7.

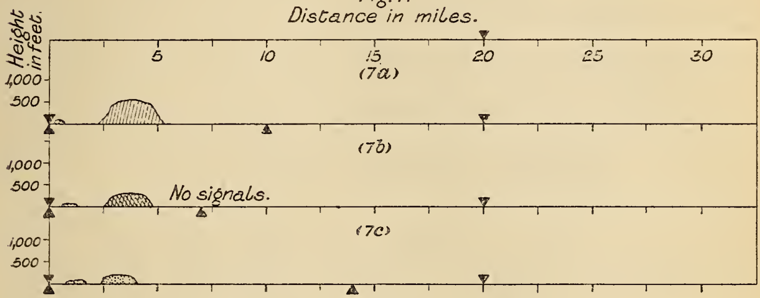
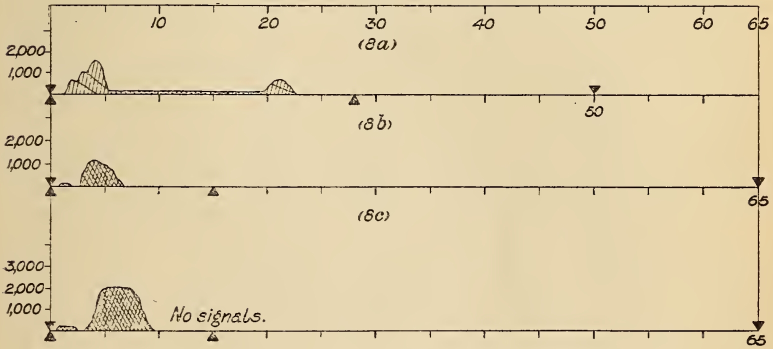


Fig. 8.



The next cause that I shall consider is that due to the varying conditions of the atmosphere; some of these conditions constitute a most serious obstacle to the effective transmission of electric waves over medium distances, and are, in consequence, a source of error likely to be encountered, and which cannot be foretold nor allowed for in wireless telegraphy.

As far as my experiences go, these effects are much less frequently noticed in temperate than in sub-tropical regions. In the Mediterranean Basin they seem to be particularly prevalent, and most persistent in summer and autumn.

Owing to their sudden advent and their equally sudden cessation, it is most difficult to carry out systematic or pre-arranged experiments, and I must therefore confine my remarks to general observations as to their effects in various parts of the Mediterranean Sea.

Reference number.	Height of aerial wire above sea.	Distance from the land.	Particulars of the land.				Height of aerial wire above sea.	Maximum signal distance.		Percentage of maximum signal distance over land to over sea.
			Maximum height.	Total thickness.	Formation, strata, &c.	Surface.		At sea.	Over the land.	
	feet.	miles.	feet.	miles.			feet.	miles.	miles.	
7a	85	$3\frac{1}{2}$	834	$2\frac{3}{4}$	Limestone..............	Scrub and wood. Wet	55	20	10	50 (T.)
7b	85	3	432	$1\frac{3}{4}$	Limestone and much iron ore	do. Dry	55	20	None at 7	Less than 35 (T.)
7c	85	3	260	$1\frac{1}{2}$	Sandstone	do.	55	20	14	70 (T.)
8a	125	1	1800	22 16 plain	Limestone. Valleys between hills	do. Wet and dry	130	50	28	56
8b	125	2	1200	4	Limestone and iron ores..	Bare. Wet and dry	160	65	15	23
8c	125	2	2060	6	do.	do.	160	65	None at 15	Less than 23

The first case is that due to the effects of lightning discharges, which may or may not be visible at the station where its effects are noticed. As a rule, with the instruments in normal adjustment, the effect of every discharge is to record a signal, the exceptions being very few.

The method adopted to observe this was to fit an electrical bell, worked by the receiving instruments, close to the observer, and at night observe the flashes and note if the bell rang.

For detailed observations, it was found more convenient to record the effects on the tape, and this was the method subsequently adopted. On the approach of the area of disturbance towards the ship, the first visible indication generally is—the recording of dots at intervals varying from a few minutes to a few seconds; secondly, the recording of three dots with a space between the first two, thus: (– ––) or *e i*, in the Morse Code, and this is the sign most frequently recorded by distant lightning; thirdly, the recording of dashes; the intervals between these then gradually decrease and merge into irregular signs, which have sometimes spelt words in the Morse Code; the effects generally die out more suddenly than they appear.

They are much more frequent in summer and autumn than in winter and spring—in the neighbourhood of high mountains than in the open sea—in southerly than in northerly winds (in the Mediterranean Sea)—in the front of a cyclonic disturbance of the atmosphere than in the rear, and with a falling barometer than with a rising one. In settled fine weather, if present, they reach their maxima between 8 and 10 P.M., and frequently last during the whole night, with a minimum of disturbance between 9 A.M. and 1 P.M.

The next cause which is intimately connected with the above, is the shorter distance at which signals can usually be received, when any electrical disturbances are present in the atmosphere, compared to the distance at which they can be received when none are present. The distance varies from about 30 to 80 per cent. compared with that obtained in fine clear weather. It does not in any way decrease with the increase of the number of lightning discharges which register their effect on the instruments, at any given time, but rather the reverse, the loss in distance generally preceding the first indications, on the instruments, of the approaching electrical disturbance.

A very marked case is given as an example: Two ships whose instruments were in perfect order, and whose sea-signalling distance was about 65 miles, opened their distance from each other on a fine, calm, bright day; when they were 22 miles apart, the signals died away, though there was no intervening land or other apparent cause for this, but it was noticed that the barometer was falling; the ships closed, and got into communication again. Atmospheric disturbances were then registered on both sets of instruments, and on the ships opening out again, no signals were obtained over 20 miles. The trials were concluded shortly after, owing to intervening land. A few hours later a heavy winter gale came on, and its approach had evidently been foretold by the falling barometer, the loss of distance in signalling, and the electrical disturbances in the atmosphere, as shown by the signals received on the instruments. No lightning flashes were observed.

On another occasion, during a period of strong but intermittent atmospheric effects, no signals were obtainable between two ships up to the usual maximum signal distance. When separated 50 per cent. beyond this distance, and immediately after a particularly strong and persistent series of electrical discharges, the latter half of a signal which was being transmitted very slowly, was correctly deciphered at a distance then considered phenomenal, with the instruments employed at the time. A few minutes later, the atmospheric effects vanished, and with them all signs of further signals, till the ships had closed to their usual signalling distance. This demonstrates that the actual electrical discharges do not of themselves reduce the signalling distance or transmission of the waves at all times, but that they may, under some circumstances, assist that transmission, possibly by a cumulative effect of the waves emitted by the discharges on the waves emitted by the transmitter, these combining and increasing the effect in the receiver. I have recorded several similar results, which I cannot attribute to any other cause.

Another effect which reduces the usual signalling distance, is one that I attribute to the presence of material particles held in suspension by the water spherules in a moist atmosphere.

The Mediterranean Sea is, for days together, frequently exposed to the force of the scirocco wind; this south-easterly wind is laden with damp, and often charged with salt from spray, and dust particles from the African coast. During the continuance of these winds, the maximum signal distance is generally less than in winds (wet or dry) from any other quarter, the proportional distance being from about 60 to 80 per cent. The effect of a scirocco wind can be and is allowed for in practical wireless telegraphy.

The causes that I have considered above, and which all tend to lessen the maximum signalling distance that would obtain under more favourable circumstances, may all be attributed to influences which are beyond the control of the designers or operators of the instruments used in wireless telegraphy.

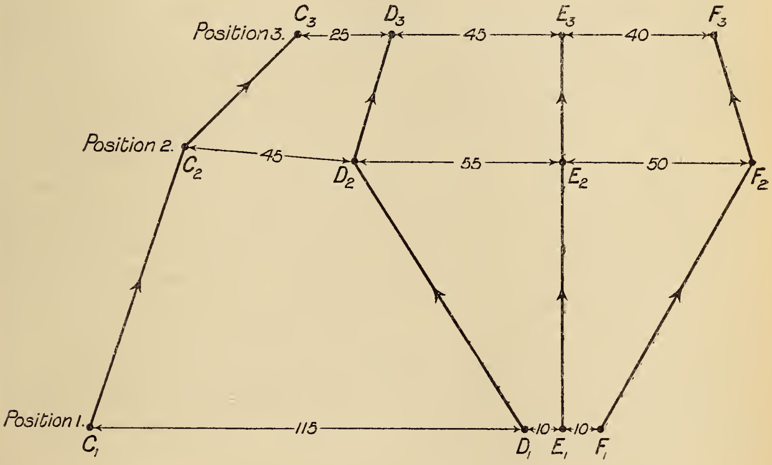
I have now, however, to consider a phenomenon which I can only assign to the apparatus in which the waves of electrical induction are generated. This phenomenon manifests itself by the gradual weakening and occasionally by the total cessation of signals, as the distance between the two ships increases, up to a certain point, and their reappearance as the distance is still further increased; in the majority of cases, the weakening of signals occurs at, or about, half the signalling distance in the open sea, under the same circumstances, which circumstances include the direct connection of the aerial wire to one ball of the induction coil used for transmission.

The three following examples are typical cases. Units of distance are given in lieu of nautical miles.

(*a.*) A ship, A, steamed away from a station, B, to ascertain the maximum distance at which she could receive signals in the open sea.

At 48 units of distance, the signals weakened, at 57 they ceased, at 65 they appeared again, and were kept up to 100 units of distance.

(*b.*) Four ships, C, D, E, F, steered as shown in the diagram, the



maximum signalling distance between each pair being about 100 units of distance.

(The results of the signals transmitted by D are those specially to be considered.)

In position (1) D's signals were received by E F, not by C.
,, ,, (2) ,, ,, ,, ,, ,, F, ,, E C.
,, ,, (3) ,, ,, ,, ,, ,, C F, ,, E.

C did not commence signalling before reaching (2) and her signals were received by D and E, and maintained by them to position (3) when the trial was finished.

E's signals, which were few in number, were received by C and D in (3), but not by D in (2).

(*c.*) In the third example, ships D and F carried out a similar trial independently. Between 45 and 55 similar units of distance no signals could be exchanged either way, though at 60 units and above, and below 40, the signalling was perfect.

To further verify that it was the system of transmission that was the cause of this cessation of signals, a syntonic method, of the same approximate frequency of transmission, though of rather less power, was used alternately with the other system. Signals were exchanged perfectly with the syntonic method, but on reverting to the other method, the signals again ceased.

This was tried repeatedly with identical results. Many other similar cases have been recorded, but the effects are not always so equally well marked, even under identical circumstances.

I consider this effect is due to want of synchronism in the oscillatory discharge between the spark balls of the transmitter. This want of synchronism has also been observed by others in the photographs of oscillatory spark discharges. C. Tissot* especially remarks that, in his apparatus (presumably used for a wireless telegraph transmitter), the images of the successive sparks are not equidistant, and that the first interval is always greater than the other intervals, which also decrease very slightly. This implies that the first wave emitted is longer than the second, and so on. Owing to the rapid damping of our form of transmitter, probably only the first two or three waves emitted are of any practical value in exciting the coherer in wireless telegraphy at a distance of 30 miles; and to excite it at such distances with the power used in these transmitters, it is probably essential that the effects of the successive waves should be cumulative in their action, and for them to be so they must syntonise with the natural period of oscillation of the receiving circuit, which period, in the cases under notice, was the mean frequency of the waves emitted by the transmitter as nearly as this could be practically adjusted.

Consider the first two waves emitted, or the interval between the first and fifth sparks of the oscillatory discharge, when the third one is not spaced midway between them; the resulting waves, differing but little in length, and moving with equal velocities and in the same direction, leave a point "O" (the spark gap), the second starting a mean wave-length behind the first one, and in the same phase; at some fixed point, "P," in their path, owing to the difference in their length, the two waves will pass that point in the opposite phase, and at a point, "Q," approximately double the distance from "O" that "P" is from "O," they will pass "Q," again in the same phase, and so on, as at all points the second wave is a mean wave-length behind the first one. *To excite the coherer*, under the conditions presumed to be necessary for long distances, the impulses due to these waves must syntonise with the natural period of oscillation of the receiving circuit, and therefore these successive waves must pass by that circuit (wherever it may be), with the second following in the same phase as the first, or nearly so,

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* 'Comptes Rendus,' vol. 132, p. 763 (25/3/01); and vol. 133, p. 929 (2/12/01).

otherwise the tendency of the second one will be to weaken or annul the effect of the first one.

At the point " P," therefore, when the waves are in opposite phase, it may be expected that signals will be weak, and at " Q," when they are in phase, they *may be* strong, but, owing to " Q's " distance from " O " being double that of " P," the effect of each individual impulse at " Q " is only half its effect at " P," and " Q " *may be* the maximum distance from " O," at which the cumulative effect of the successive waves will excite the coherer, even when they are in phase and in perfect syntony with the receiver circuit.

I have not yet been able to investigate the exact cause of the non-synchronous emission of the waves, but I attribute these " zones of weak signals " (as I term them) to this non-synchronous emission of the waves, and to the rapid damping of this form of transmitter, and would observe that when using my syntonic transmitter, in which the damping is less rapid, I have never noticed these effects.

A point of interest, which has also great effect on the signalling distance, is the efficiency of the earth connection of both the transmitting and receiving instruments. Fortunately for the system, on board a modern ship there is no difficulty in obtaining an almost perfect earth connection when the ship is at sea. In dry dock, however, there is, in fine weather, a great difficulty in doing so, and the effects of the bad earth with the ship in dock, on the signals, are extremely marked, both for transmitting and receiving, reducing the distance as low as to 25 per cent. of the distance with the ship afloat.

A similar effect due to drought has been observed with some shore stations, where, according to my experiences, the maximum signalling distances have always been obtained during wet seasons of the year.

A typical example is given :—

On one particular occasion, towards the end of a very dry summer (last year), the maximum signal distance between a certain ship and station, 500 feet above the sea, was 38 miles, the usual distance having previously been 68 miles. Two days later, during which time no alterations whatever had been made to the adjustments of the instruments, but which included 24 hours of heavy rain, the maximum distance obtained was 70 miles, which has since been maintained.

Repeated experiments with and without earths on the transmitter and receiver have shown me that, in the open sea, signals may be obtained up to 50 or 60 per cent. of the full distance, without earths on the receiver, though such a large proportion is unusual, the average being 30 per cent. A condenser of suitable capacity acts nearly as well as a good earth ; without an earth on the transmitter, the percentage of distance has never exceeded 15 per cent. Using good earths, but no aerial wire whatever on the receiver, or near it, signals have never been obtained over 3 miles. With no aerial wire on the transmitter I have never known a signal to be received on board another ship over 2 miles distant.

My experience demonstrates most clearly, and with no marked exception, that, for signalling any distance beyond a few miles, the combination of aerial wires and good earths is essential, for both transmitting and receiving instruments.

Summary.

The results of my observations may be briefly summed up as follows :—

(1) That intervening land of any kind reduces the practical signalling distance between two ships or stations, compared with the distance obtainable in the open sea, and that this loss in distance varies with the height, thickness, contour, and nature of the land; and that, based on the results of these observations, it may be concluded that some of the waves of electric induction, transmitted by wireless telegraphy, may pass through, over, and possibly round the land, and are comparable to the passage of ocean waves through or over a reef, or round high land, which waves proceed along their course with diminished energy, after passing such obstructions.

(2) That material particles, such as dust and salt held in suspension in a moist atmosphere, also reduce the signalling distance, probably dissipating and absorbing the waves.

(3) That electrical disturbance in the atmosphere also acts most adversely to the regular transmission of these waves, in addition to affecting the receiving instruments by lightning discharges.

(4) That a system of transmission in which the oscillations are rapidly damped is irregular in its action on distant receivers, owing to the irregularity of the train of waves giving rise to different types of disturbance at different parts of their path, which may not have at certain points the necessary cumulative effect on the receiving circuit.

(5) That the earth's function in the transmission of waves is most important; but that its importance is secondary to that of the aerial wire, or capacity insulated in the air above the surface of the surrounding sea or earth.

I have to thank many of my brother officers and men in H.M.'s Navy for the valuable assistance they have ungrudgingly given me in carrying out my experiments.